IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appln. Of:	MADOCKS		)
Serial No.:	10/036,067		)
Filed:	October 19, 2001		)
For:	PLASMA TREATMENT APPARATUS		)
Group:	1763		)
Examiner:	Zervigon, Rudy	DOCKET: 10630/9	)

Commissioner of Patents & Trademarks
Washington, D.C. 20231

DECLARATION UNDER 37 CFR 1.132

I, JOHN MADOCKS., hereby declare:

1. I am the Applicant in the above-referenced Application.

2. I have attached figures hereto to explain the difference between the device described in U.S. Pat. No. 3,955,118, in the name of Flemming, and the device described and claimed in my pending Application having Serial No. 10/036,067.

3. Referring to Exhibit "1" hereto, FIG. A shows a perspective view of Flemming's apparatus.

4. FIG. B shows a cross sectional view of Flemming.

5. Referring to Exhibit "2" hereto, FIG. C shows a cross sectional view of Flemming's device disposed adjacent a substrate.

6. FIGs. D, E, and F, graphically illustrate the modifications that would be required to the device taught by Flemming in order to create the plasma source claimed in my new claims 34 through 43.

7. FIG. D shows Flemming's device being rotated 90 degrees relative to the substrate.

8. FIG. E shows a relocation of part of Flemming's anode.

9. FIG. F shows relocation of Flemming's electromagnet.

10. The structural differences between the device taught by Flemming and the device claimed in my pending application result in completely different modes of operation.

11. Referring to Exhibit "3" hereto, FIG. G, Flemming's device comprises a magnetic field disposed within the process chamber.

12. Referring to FIG. H, my claimed device comprises magnetic field lines disposed between the two cathode elements comprising the top portion such that a portion of the magnetic field extends outwardly from the top portion of my claimed device.

13. Exhibit "4" hereto is a copy of Chapter 6.6 from Roth, Industrial Plasma Engineering, Vol. 1, Institute of Physics (1995) (hereinafter "Roth").

14. Referring now to Exhibit 4 at page 205, FIG. 6.11 illustrates a Penning ion source as taught by Flemming, and shows the magnetic field confined to the process chamber.

15. The undersigned declares further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to

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be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

JOHN MADOCKS

Date: 2-8-05

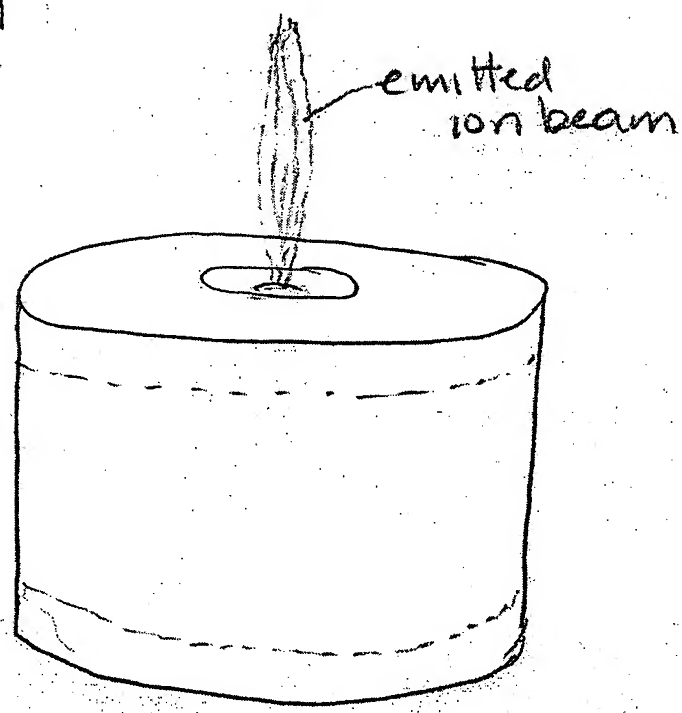
RE: Declaration Under 37 CFR 1.132
Serial No. 10/036,067

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class Mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on February 8, 2005 at Tucson, Arizona.

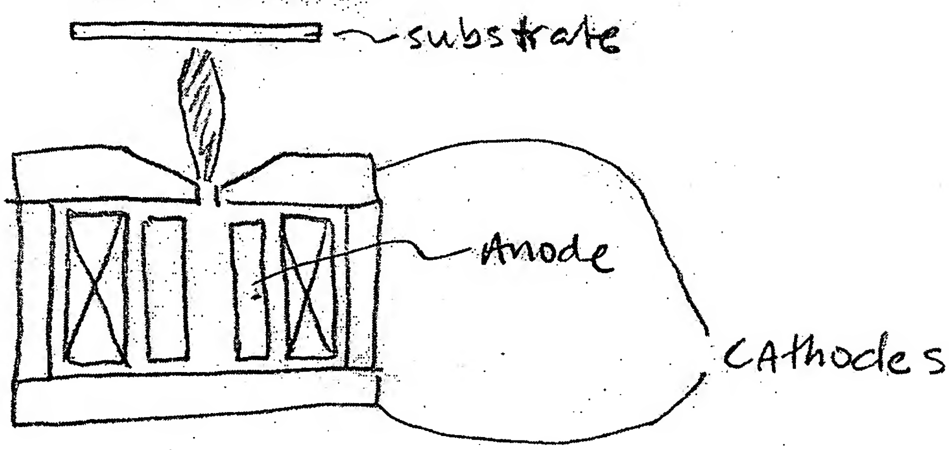
By: [signature]

FIG. A



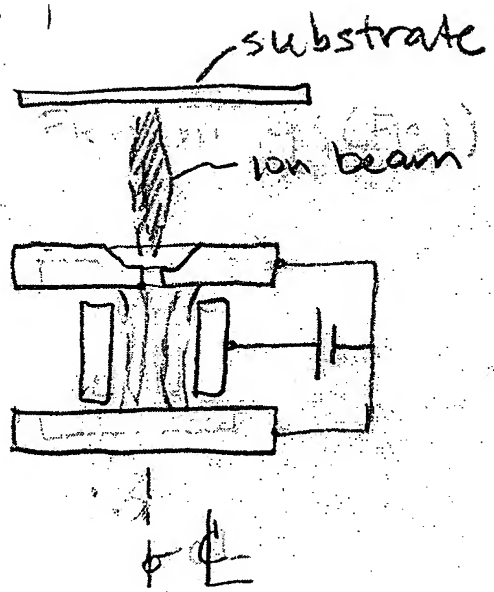
3D View of Flemming
w/ extractor nozzle
not shown

FIG. B



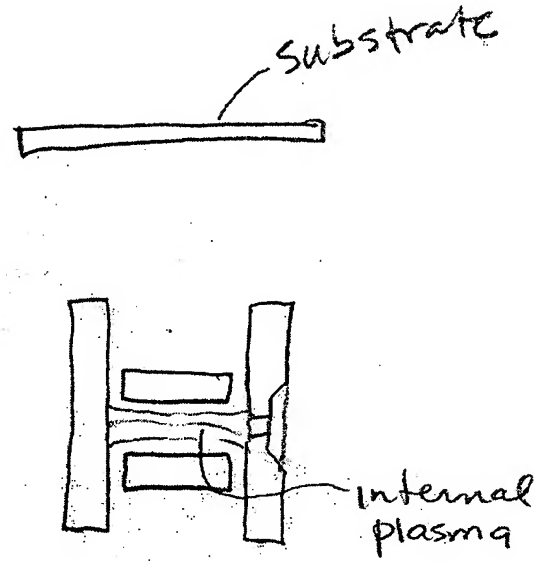
section view of
Flemming
(FIG I of '118)

FIG. C



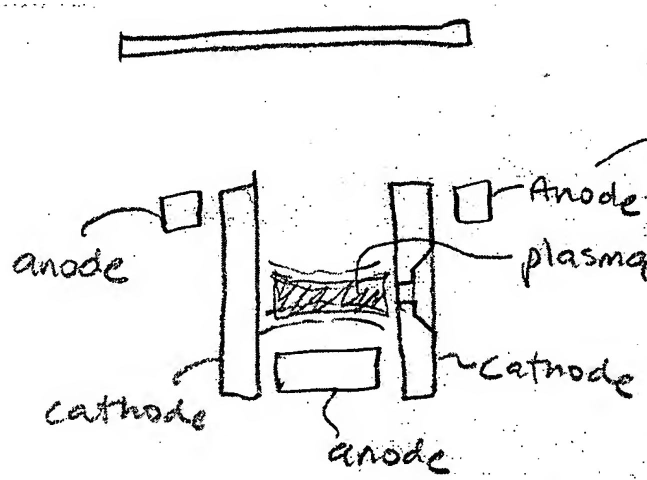
Flemming (FIG 1)

FIG. D



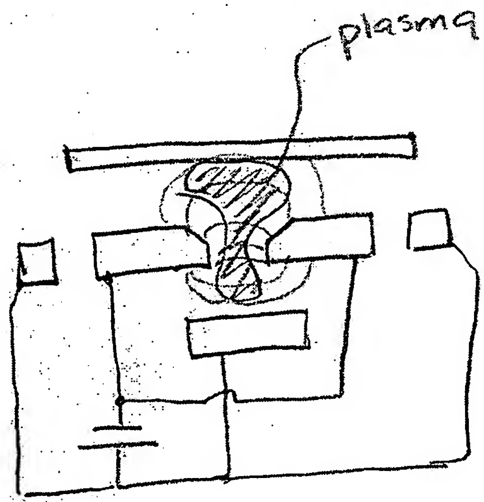
turn Flemming 90° to substrate

FIG. E



move part of anode near substrate to outside of source

FIG. F



change shape of cathodes, move electromagnet out of way, move closer to substrate.
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FIG. G

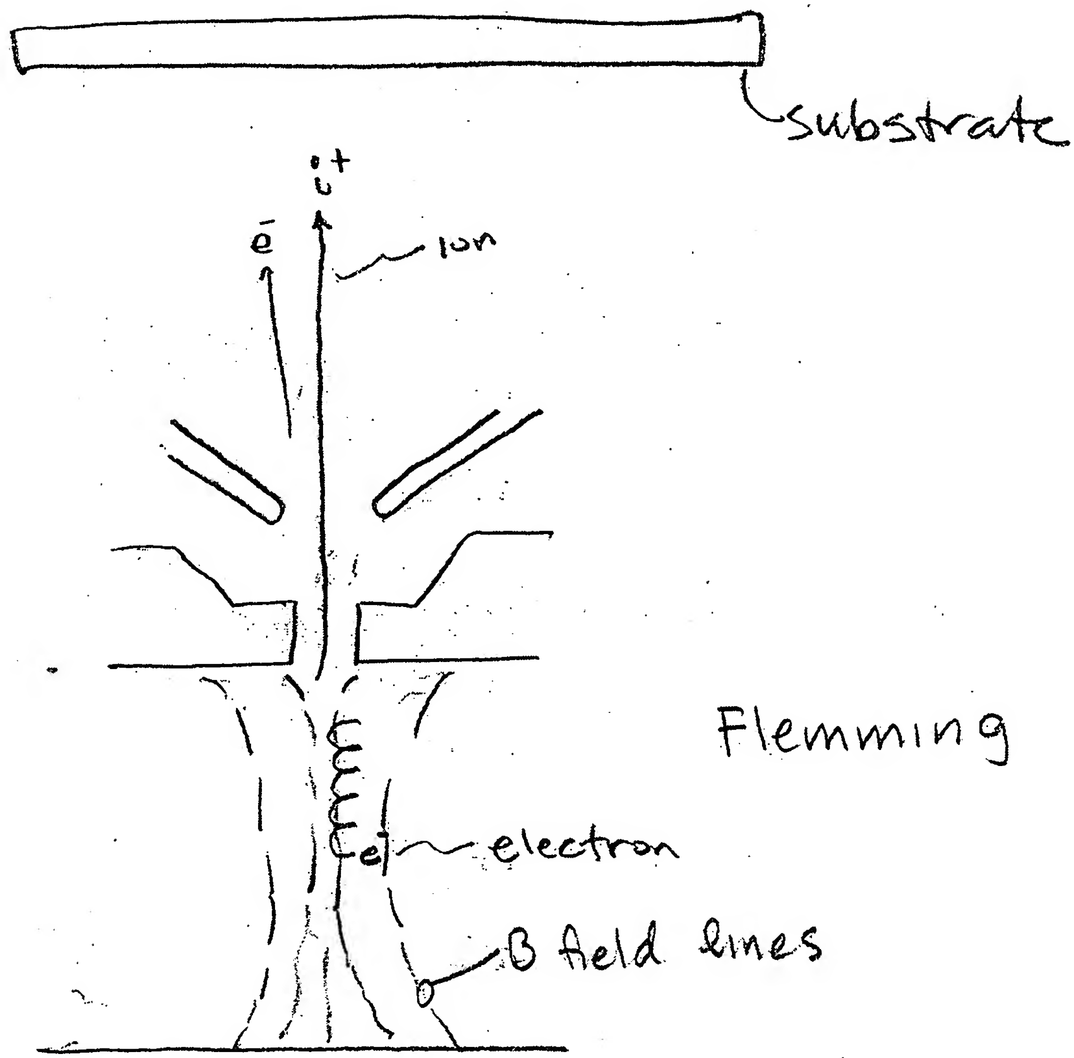
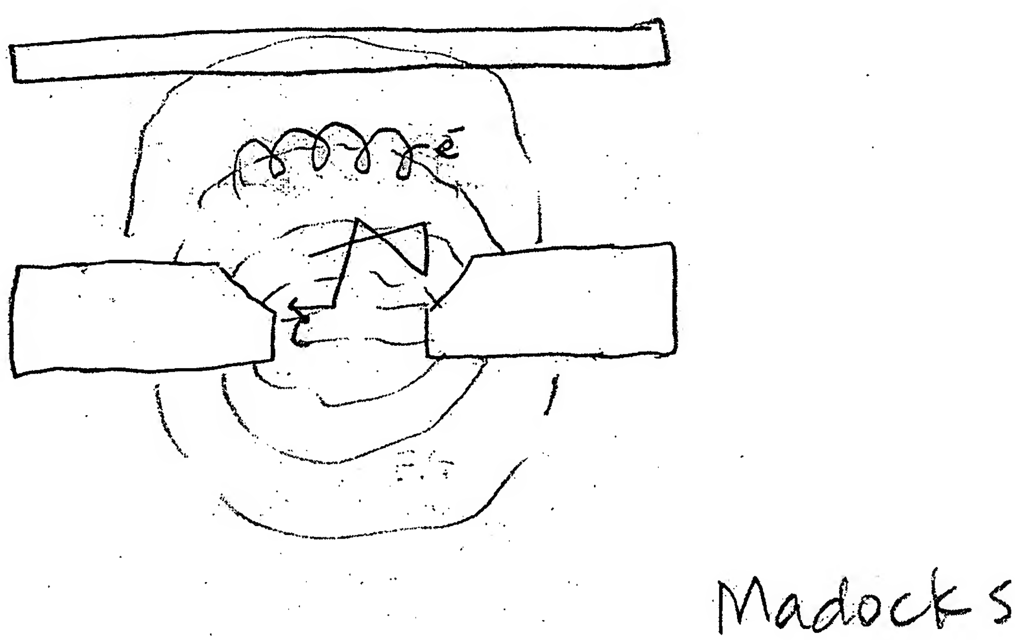

Substrate
i^+
$\bar{e}$
ion
Flemming
e
electron
B field lines

FIG. H


$\bar{e}$
Madocks

The least useful axisymmetric magnetic field configuration is the uniform field along the axis of the discharge chamber shown in figure 6.10(b). Here, the plasma tends to be constrained to the field lines in contact with the hollow cathode surface. The most efficient of the axisymmetric magnetic field configuations is that shown in figure 6.10(c), in which the magnetic field diverges from the hollow cathode ionizer to the accelerating grid, with the magnetic field line connecting the edge of the hollow cathode just touching the end of the discharge chamber. This arrangement spreads the plasma relatively uniformly over the surface of the accelerating grid. Finally, the over-divergent field, shown in figure 6.10(d), is less efficient, because of the direct transport of ions along the magnetic field lines from the cathode to the anode.

6.5.3 Operating Characteristics

The Kaufman ion source developed for space applications had accelerating voltages ranging from 1 to 10 kV, total beam currents ranging from 0.05 to 10 A, current densities that ranged from 0.70 to 0.95 of the space-charge limited values, and beam diameters that ranged from 10 cm to 1.5 m (Kaufman 1965, Poeschel *et al* 1979). The lifetime of sources of this type which were intended for space applications could exceed 10 000 hours. The Kaufman ion source was by far the most extensively developed of any ion source during the period from 1958 to the present and has been widely applied industrially to ion beam sputtering and ion milling of surfaces.

6.6 PENNING DISCHARGE SOURCES

The Penning discharge was developed by Frans Michel Penning (1894–1953) in the 1930's (Penning 1936, Penning and Moubis 1937), and was modified into an ion source by R G Meyerand and S C Brown (1959).

6.6.1 Penning Configuration

A *Penning ion source* similar to that developed by Meyerand and Brown is shown schematically in figure 6.11. The Penning ion source consists of a magnetoelectrically confined plasma discharge, in which gross confinement of electrons is provided by an axial magnetic field and an axial electrostatic potential well. Electrons are electrostatically trapped axially, and magnetically trapped radially until they collide and ionize, enabling the plasma to be maintained at background neutral gas pressures as low as 10^{-7} Torr (1.33×10^{-5} Pa). The electron–neutral ionizations avalanche until the ionization and loss processes reach a steady state. Starting electrons for the Penning plasma can be provided

Roth Industrial Plasma Engineering
Vol. 1 Institute of Physics Pub. 1995

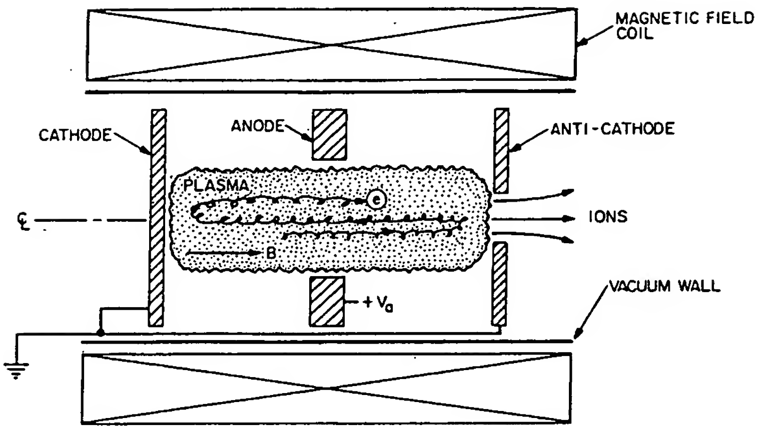


Figure 6.11 The Penning ion source, with a cylindrical anode ring at the center and two cathodes at either end. A small hole on the axis of one cathode allows a beam of ions to escape.

by volume ionization from background radiation, secondary emission from cold cathodes, a hot filament as shown in figure 6.12, or a hollow cathode.

Although the axial electrostatic potential distribution is a potential well for electrons, it repels ions produced between the anode and cathode. If a hole is opened up in one or both cathodes, ions, instead of impacting the cathode, will pass through, producing a relatively intense beam of ions, as noted by Meyerand and Brown (1959). Penning ion sources can be operated at gas pressures between 10^{-7} Torr (1.33×10^{-5} Pa) and 100 mTorr, (13.3 Pa), magnetic inductions from 0.01 to 3 T, anode voltages from 100 to 50 000 V, currents from 10^{-7} to 20 A, electron kinetic temperatures from 2 to 15 eV, and the ion energies produced can range from less than 1 eV to several keV.

6.6.2 Ion Heating in Penning Sources

It is an interesting property of the Penning discharge as an ion source that it can produce a beam of ions with kilovolt kinetic energies, far higher than the kinetic temperature of the background electrons (Meyerand and Brown 1959, Roth 1966, 1973a, b). The high ion energies associated with Penning sources result from the circumstance that Penning discharges can have radial electric fields in excess of 1 kV/cm between the plasma and the anode. This leads to magnetoelectric heating by E/B drift in the azimuthal direction, with a velocity

$$v_d = \frac{\boldsymbol{E} \times \boldsymbol{B}}{B^2} = \frac{E_r}{B}. \tag{6.18}$$

The kinetic energy corresponding to this drift velocity is given by

$$\mathcal{E} = \frac{1}{2}mv_d^2 = \frac{m}{2}\frac{E_r^2}{B^2}. \tag{6.19}$$

Thus, in Penning discharges, the particle energy is proportional to mass, and this is why ions in low pressure Penning discharges are often more energetic than the electrons.

At pressures below 30 μTorr, and at magnetic fields above 0.2 T, Penning discharges become very turbulent, and can provide a Maxwellian distribution of ions with kinetic temperatures up to several keV (Roth 1973a, b). One can also adjust the operating parameters to achieve a uniform distribution function of ion energies over the range $0 < E < E_{max}$, where E_{max} is given by equation (6.19). At higher gas pressures, above 100 μTorr, nearly monoenergetic ion energy distributions at the Penning anode voltage are observed. These ions acquire high energies by falling down the electrostatic potential gradient between the anode and cathode.

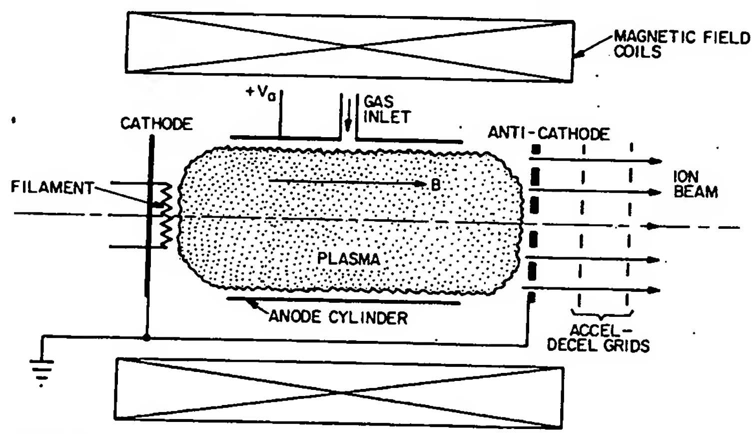


Figure 6.12 A Penning ion source in the duoPIGatron configuration, in which electrons are emitted from a filament or a hollow cathode on the left-hand surface, and generate a Penning plasma between the cathode and anticathode. In the duoPIGatron, the working gas is injected radially into the anode cylinder and ions are extracted through holes in the anti-cathode, which may be replaced by an accelerating grid.

6.6.3 Other Penning Configurations

Penning ion sources can be operated in the *duoPIGatron* configuration, which was developed as a fusion-related ion source at the Oak Ridge National Laboratory by Stirling, Morgan *et al*. This modification of the

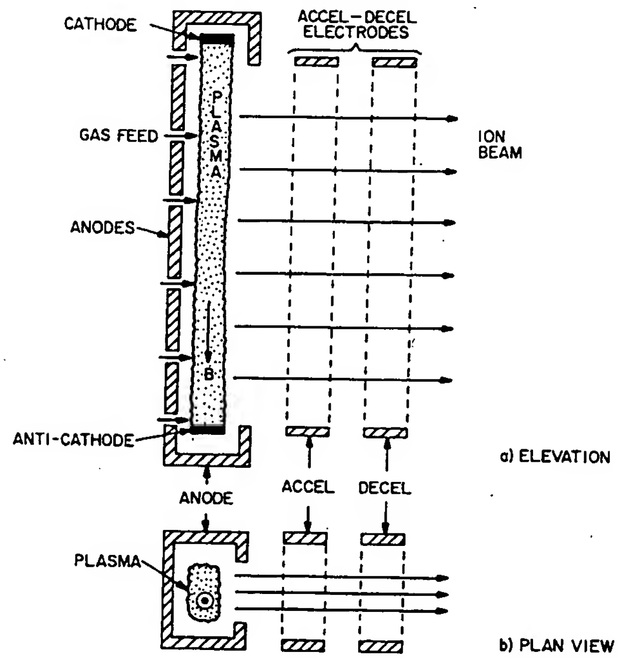


Figure 6.13 A Penning ion source in the Calutron configuration, in which a long, narrow beam of ions is produced. The ions are created in a Penning discharge, shown in the elevation view, which has a uniform magnetic induction along its axis. Ions are extracted along the length of this plasma and accelerated by an accel–decel electrode configuration.

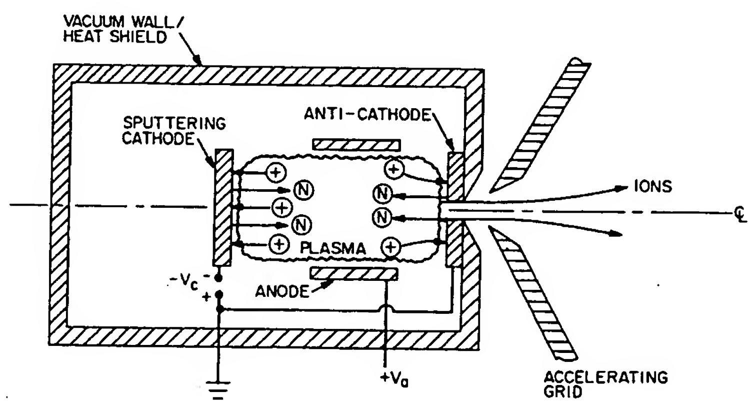


Figure 6.14 The sputtering ion source, a Penning discharge in which the left-hand cathode is biased to attract ions, and after being heated to incandescence, boils off neutral atoms which are ionized in the discharge, and extracted through the anti-cathode to form an ion beam.

Penning discharge is shown in figure 6.12, in which the Penning ion source provides ions to an accel–decel configuration.

The *Calutron* is a Penning discharge with ions drawn normal to the axis of a long, thin Penning discharge, as shown in figure 6.13. The Calutron was originally used for electromagnetic separation of isotopes, where a long, thin beam of ions was required.

The *sputtering ion source* is a Penning ion source in which atoms of refractory materials are ionized in the Penning discharge plasma to form an ion beam, in the manner indicated schematically in figure 6.14. In this source, ions bombard the Penning cathodes, which are made of the refractory material which it is desired to form into an ion beam. The cathodes are heated to the point at which neutral atoms of the cathode material either sputter or evaporate from the surface, become ionized in the Penning plasma, and are then accelerated through the cathode on the left, to form an ion beam.

6.7 BEAM-PLASMA ION SOURCES

The *beam-plasma ion sources* have in common the use of an electron beam or linear DC arc discharge between a cathode, usually a heated filament, and an anode. The interaction of the electron beam with a gas of the

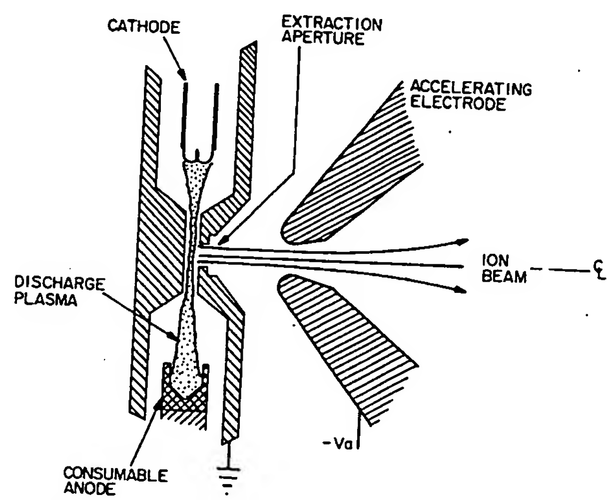


Figure 6.15 The capillary arc source. This consists of an arc drawn between a cathode, and an anode shown on the left. The capillary arc terminates on an anode which is heated and the material of which is vaporized. Atoms vaporized from the anode are ionized and extracted radially through a small hole in the capillary where they are accelerated into an ion beam.